// THE VIRGINIA TEACHER

VOLUME IX OCTOBER, 1928 NUMBER 8

THE SCIENTIST AND EDUCATION

THIS title requires some restriction, since I shall consider the relation to education of those scientists only, who are engaged in educational work. The industrial scientist and the research scientist connected with non-teaching institutions have very important relations to education, but these relations I shall not attempt to treat. Let us for the moment center our attention upon the relation of scientists in educational institutions to the educational phases of their work and to the educational situation in general. Within this scope let us keep in mind especially the social and industrial needs of Virginia and the educational conditions in the state. There is time in our program for only a suggestive treatment—not for an exhaustive one. I hope it may not prove an exhausting one.

Let us recognize at the outset that the professional scientist has no patent upon the scientific method, no prescriptive right to the possession of scientific knowledge, no vested interest in its benefits, no exclusive claim upon the designation of scientist.

We are all scientists! In saying this I do not mean to imply that a certain elimination has been exercised in the admission to this hall, rejecting all who do not exhibit the insignia of an exclusive fraternity of scientific men. On the contrary, all who have any interest in our exercises have been invited and are cordially welcomed. Furthermore, even those who, by reason of indifference to the attractions of our program, remain in outer darkness are also scientists. Every man capable of education is to some degree a scientist. He observes through his various senses the animate and inanimate objects about him. He perceives processes and conceives relations among these material objects. He reasons with more or less skill, cogency, and completeness concerning the world about him. He makes generalizations more or less profound and applies them in his subsequent behavior. For some of these scientific processes there is obvious need if not necessity. Others are indulged in as a result, let us say of idle curiosity. This common human being is an applied scientist, but he is also a pure scientist. Yes, every man stands at some level of scientific advancement.

Some men arrive at notions at variance with yours and mine, notions indeed flatly contradictory to those held by great groups of individuals; these have arrived by faulty application of scientific methods, at notions that we regard as primitive, fantastic, unfounded, untrue. Some men, early adopting a generalization that the masters or professors or writers are the media of all knowledge, abandon their progressive scientific endeavor to observe with their own senses, to use their own intellects in organizing knowledge, and rest in utter dependence upon authority. The level of scientific development of this numerous class of men is that characteristic of the Dark Ages. We recall, in contrast with these, men who have made rigorous use of scientific methods. The *seal* of our Academy bears the name of Clayton, the pioneer botanist and keen observer of nature, faithfully utilizing every opportunity to catalog the plants of the wilderness; of Jefferson, far-seeing patron of science, keenly appreciative of its attractions and its benefits; of Maury, skilled Pathfinder of the Seas; of Reed, the conqueror of yellow fever—each in his century leading in the applications of the methods of science to the problems of his day. Not only in the work of the pioneer or the research worker is the scientific method of use. In the multitudinous affairs of everyday life we are each confronted with situations involving observation, comparison, judgment, reason; *i. e.*, involving scientific analysis, hypothesis, and verification. Who is it—farmer, business man, carpenter, banker—that is free from such situations! Whose success or failure is not dependent to a large extent upon the readiness with which he correctly solves these situations? None, perhaps, unless such as the factory worker who serves monotonously, day by day, a certain machine. Each, according to the degree to which he follows scientific methods of analysis and guides his affairs by scientific knowledge, merits the name of scientist.

Every normal child is a scientist. From birth he receives sensory impressions of objects about him and early learns to make practical judgments concerning them and to apply these in his daily affairs. He makes a good start in the development of his scientific powers. He observes, he eagerly attacks new problems that present themselves, he learns as a result of experience, he makes fairly effective use of his knowledge. But he is still far from being equipped physically, mentally, socially, spiritually, for the life and work of a man. Great growth is essential if he is to enjoy the satisfaction of maturity in whatever sphere the future may find him. The scientist may well give earnest consideration of the problem as to what part the study of sciences should play in his development. His progress through school and college should see a constant accumulation of scientific knowledge, a continuing development of skill in acquiring and applying this knowledge and a growth of ideals associated with or derived from study of sciences.

As the most direct and obvious end to be attained in the teaching of sciences we should mention the building up in the mind of the student of a fund of knowledge. I say a fund of knowledge, not merely a catalog of facts—a fund of related facts, of ordered facts, facts regarding the physical universe and man in all his aspects. With adequate time devoted to studies in science, including continuous science work in the secondary years, there is no good reason why every pupil should not cover the field of the sciences with a fair degree of completeness and possess at graduation from high school a speaking acquaintance with the facts and more elementary principles of all sciences. In this age of dependence upon controlled physical forces, chemical processes, biological relationships—surely in our age of science this is an essential feature of adequate education.

Along with the acquisition of knowledge by the pupils, should go acquisition of skills of various types—skill in the use of the senses in observation, skill in analysis, skill in the combination of analysis and observation and judgment which we call experiment, skill in the formation of correct judgments, skill in carrying out logically a train of reasoning, skill in bringing available knowledge to bear upon new situations. It is not to be expected that these skills will be perfected in school, in college, or in life. But the beginnings of the early years should be continued; there should be constant building on the foundation previously laid. The utilization of these skills in the application of knowledge to daily affairs should become a fixed habit. For the acquisition of knowledge within the field of the sciences and the development on the part of the pupil of the special skills peculiar to this field, scientists must have primary responsibility and of this responsibility they should be keenly aware.

In addition to these features of education in which the sciences are almost exclusively concerned, there are others in which the sciences go hand in hand with other subjects as means to educational objectives. Among these may be mentioned ideals, appreciations, aesthetic and ethical standards.

Even in the accomplishment of the more

common objectives of education, objectives for which the sciences are not regarded as essential elements, the study of the sciences may be of very great service. I will refer for example to training in effective understanding and use of language. Words representative of material objects or physical processes known to the child are easily learned and remembered and readily used. The use of words to represent relations is also comparatively easy, provided the child's experience is sufficient for the complexity of the relation and this relation is really clear to his mind. But the further we depart from material objects and physical processes in our use of language the more difficult it becomes for the child. To learn to use language in connection with ideas remote from physical phenomena is at best a long and laborious process. In it the learner is beset by two dangers. The lesser one is that he will abandon the attempt and remain satisfied not to think beyond the immediate range of tangible objects. The other danger is that in addition to abandoning the attempt to use intellectual processes dealing with intangible concepts, the student may acquire the habit of merely imitating the use of words by others without himself grasping their meaning or possessing the ideas they appear to represent. Every teacher needs to be constantly on guard against this very strong tendency. Now for bridging this gap between objects and abstractions, in leading the student to use language with precision, the materials of physical sciences are of utmost value. In other fields efforts to guard against this danger and to keep language significant are made under serious handicaps. But in the sciences the objects are constantly at hand and training may be as completely centered about objects as may be desired. Detachment from objects may be accomplished as development of the individual permits. Generalization, safeguarded by adequate checks, may be accomplished by easy and obvious stages.

The period of formal instruction in school or in college is short in the normal life of a man, short in view of all the knowledge that our race has accumulated, all the skills we covet, all the vast unknown we would know, the apparently impossible tasks we would do. The period of learning may be most effectively lengthened if, during the period in school and college, the pupil retains or develops an inquiring mind. For the scientist the habit of inquiry is essential. For the teacher of science no quality is more fundamental. He must feel the challenge of the unknown. He may be unable to meet with appropriate action any particular challenge. Other interests and duties may take precedence but its appeal must be recognized, its pull must be felt. The skilled teacher will lead his pupils to recognize the limitations of their knowledge, recognize the *present* limitations and be *unsatisfied*. This desire to know is immensely enhanced by the realization that it can be satisfied by one's own effort. A demonstration of this fact is valuable in any field; it can be made with perhaps greater readiness in the sciences than in any other. I believe that nothing stimulates so greatly the desire to know as an experience in the search for knowledge that is new not to the searcher only but new to the experience of mankind. To the cat, as food a mouse is a mouse; and to us knowledge may be equally valuable new or old. But playing with old knowledge, like the cat's toying with a caught mouse, cannot bear the zest that attaches to the search for the unknown, cannot take the place in exercise of the scientific habit of the quest of knowledge that is brand new. I believe that research has not yet attained to its rightful place in education, that we have not yet realized its wide application and stimulating possibilities. Under guidance even the embryo scientist may experience the joy of discovery and actively contribute to the sum of human knowledge or to the devices that transmute human knowledge into other human goods. That David Putnam and Deric Nusbaum are making interesting and important discoveries as explorers is not so remarkable as that we have been so long in discovering the possibilities of such work in a boy's education. Especially in the sciences is there opportunity for exposing the beginner to some of the exhilarating experiences of the explorer and to utilize these experiences in early education.

One of the most serious needs of our educational work outside of vocational and professional schools is the need of making connection between knowning and doing. I should rather say the need of completing knowledge by making it effective. In the sciences above all other subjects, problems are ready at hand. We could improve much of our teaching by more emphasis upon the application of principles we teach. I am not at this point particularly advocating applied science as compared with pure science. I am rather advocating the point of view that a principle is best learned and one's knowledge is best tested through consideration of specific cases. The applications I have suggested may be as purely scientific as Pasteur's research concerning spontaneous generation. They constitute tests of the generality of the principle, of our understanding of its scope. Above all they give us exercise in testing and applying and they develop in us the habit of following principles through to their confirmation or contradiction. They develop the habit of problem solving. Emphasis should be placed at appropriate times upon distinctly practical problems and their solution, but any type of problem that strengthens the tendency to put principles to work is of value.

We have briefly considered some of the possible values that may be derived from the study, and for the most part the elementary study, of the sciences. We make no claim that these advantages are confined to the study of the sciences; but surely the study of these subjects contributes to education elements not secured so readily by means of any other materials. And, let it be noted, these elements are of value alike to persons of most diverse prospective occupation. Scientific knowledge, skill and resourcefulness, accuracy of expression in one's language, an inquiring and applying mind—these are of value to the future business man or historian, the philosopher or the artist, the mechanic or the university professor. This training is not especially for the research worker but for the pupil of an elementary school whatever his future career. We should aim to develop in every capable person, at least such scientific knowledge and skill as will enable him to avail himself of the benefits of scientific discovery and to realize a share in its satisfactions. Familiarity with physical objects, understanding of the principles of science, ability to execute logical judgments and to reason cogently, an investigative attitude, facility in applying one's relevant knowledge to a present situation, these are advantages we must strive to secure for our young people in increasing degree as they progress in our schools.

I shall not attempt to catalog, much less to set forth in detail, the respects in which the product of instruction in our schools and colleges falls short of the possibilities suggested. The claim has been made that education in and through the sciences has been a failure. I think any fair minded person at all familiar with the educational situation will recognize that this claim exaggerates the faults of science teaching. At its *best* it has justified itself in high degree. But no claim that education in science has failed here in Virginia can be substantiated, since it has never been tried. The O'Shea survey of education in Virginia reports that in sixteen cities, elementary science occupied 3.5% of the pupil's time in school. Certain elements of science are included in other categories and certain other allowances must be made in fully considering this figure. It is, at best, painfully clear that utterly inadequate attention is being given to materials of science in our elementary schools and that, with the lack of proper basis and with additional handicaps, the secondary schools are giving inadequate training alike in their science subjects and in tool subjects utilized in the sciences.

In place of apt characterizations and neat distinctions expressed in fitting language by the product of our schools, we hear "wise cracks" expressed in monotonous terms that have lost through senseless repetition what picturesqueness and vigor might have attached to their original use. By the time they have completed secondary school, our pupils have practically abandoned the use of their eyes, their ears, and their other senses as a means of first-hand knowledge. If asked what is before their eyes, they wiggle and squirm, endeavoring to find opening for an inquiry, however ingenuous it may appear, absolutely unwittingly designed to entrap you into an indication as to what you wish them to see. Again and again, as utterly deluded as they are honestly convinced, do they say "I can see but I cannot draw." Test a class in psychology on distinctions of taste. Time and again the blindfolded student with salt on his tongue will fail to name it. If asked what it tastes like, how often does he fumble about for a suggestion as to what you used on the preceding subject or what your outline may call for. The Dark Ages of learning are not yet past. You decide to present a subject chiefly by lectures. After a few little tests have been given bearing upon the efficacy of your instruction and the tests have been criticized, graded and returned, will not earnest and conscientious pupils come to you asking for a text to lean upon—"I cannot get your lectures." Suppose on the contrary that you decide to use a text as the chief source of information for the student and base your class discussion on that. Will not the same students, after an estimate of their success has been rendered them, beg you to present them information in lectures—"I cannot get this text." Let us admit our own responsibility for a large share of the difficulties our pupils experience in learning; but when due allowance is made for defects in presentation, evidence remains that, by and large, graduates of our secondary schools do not read, they cannot read. The contact between things and words has been so completely severed that language to them no longer represents ideas—it is empty of meaning. The re-establishment of connection between words and things is often the most pressing necessity in their education—and a difficult process indeed at a level where elementary education is supposed to be long past. And this process is *elementary* education whether carried on in its proper place or in secondary school or college. In the correction of this defect, the work in sciences may well have a large place.

After what I have said it may be superfluous to admit that we do not do in college the grade of work we should do. But let us make no excuses. In one way or another the responsibility is ours. On the whole we cannot blame our pupils for their failures—a more earnest and painstaking body cannot be found. Let the scientists of the State acknowledge a responsibility for providing for these young men and women fuller advantages in education, especially as concerns the sciences, than they have enjoyed.

As one feature in the discharge of this responsibility for education in the sciences I wish to urge research in the teaching phases of our work. If research leading to improvement of teaching in sciences is to be done, it must be done by the teachers themselves. I want to commend in this connection the attitude toward taxonomic work attributed to Alfred G. Mayer. He is reported to have maintained that every biologist owes it to his profession to deal with the systematic classification of some group of organisms. In accordance with this principle he produced a magnificent monograph dealing with the jelly-fishes of the world that will long be a standard of immense service to his fellow workers. So each teaching scientist should feel under obligation to his profession to make at least one substantial contribution to the technique of presentation of his subject or to the adaptation of the material in his field to the process of education. The scientist is intrigued by problems. Let him see in his teaching the scientific problems there encompassed. Such research would have, as a most valuable by-product, increased interest on the part of the teacher in all phases of education.

A word of caution may be given as to the manner in which improvement in teaching may be brought about. The favorite method, in harmony with a widespread movement of the day, is through the appointment of supervisors. Already this movement has attained great momentum in elementary schools. It has spread to secondary schools; and proposals for extending it to higher education are already heard. It has possibilities of yielding prompt results of value; it has also its dangers. Insofar as it supplies capable *leadership* of co-operating individual teachers it is well. When and insofar as it degenerates into direction of unskilled teachers and removes the incentive to individual initiative and resourcefulness, it will dismally fail. In secondary and in higher education such a method has no place. Even in elementary grades it is possible that methods better adapted to the genius of our people and the principles of democracy may be found. I make bold to commend to the attention of students of elementary education the Grade-Leader Plan as developed in the elementary schools of Lebanon, Pennsylvania. (see Rorem, S. O. '27-8-13. *School and Soc.* 26. p. 205-207). Certainly if the development of education in sciences and utilization of the sciences in education are to proceed, scientists must give attention to the matter, must inform themselves more fully and widely upon it and must have a larger voice in the consideration of educational programs and policies.

It is high time that the movement for more adequate treatment of the sciences in Virginia education should gain momentum. Our industrial and economic life is undergoing a change that places new demands upon our people and offers to them new opportunities. New opportunities for skilled and professional work will be open to those who are prepared for it. Broader and more thorough education is needed as a basis for the quickened life of the new day. Our people as a whole need to understand and appreciate the place of the sciences in the economic life of our time. It must almost make even professional scientists rub their eyes to learn of the constantly tightening ties between science and industry. The Chairman of the Board of a great electrical concern, a captain of industry but a layman in science, recently spoke as follows:—"There are new explorers at work, bringing into the area of possible business operation fields vastly greater than any geographical explorers found. I refer to the research workers in pure science, who are pushing back the horizon and vastly enlarging our fields of knowledge. New materials are being put into our hands from the most unexpected as well as most commonplace quarters. New forces, heretofore undreamed, are shown to be available. I can see a picture of these adventurers in pure science moving out into unknown fields as the great geographical explorers set sail for unknown lands. Following them are the applied scientists learning how to use the new forces just as the early settlers followed the old adventurers. Finally business organizes itself to harness those forces and put them to work." The movement is on. Will Virginia join in it? We should have this revolutionary development in mind as we deal with students who will shortly be the leaders in both science and industry.

I am fully aware that I have said nothing new. Since the inspiring example of Huxley, at least, scientists have been making contributions to education and have been taking part in its councils. The members of our Academy and the organization officially have indicated active interest in educational matters. Witness the symposium on the nature and content of first courses in psychology held this afternoon and the papers listed in the Chemical Section for the Round Table Discussion on Chemical Education tomorrow morning. Attention to these matters has been increasing. They demand still deeper study.

I have endeavored to call attention particularly to the needs and opportunities of the present day in education in Virginia and the relation of scientists to it. It is my earnest belief that, in view of existing conditions, the scientists of Virginia should consider most carefully the scientific needs of the industrial situation; that they should give greater attention to educational problems and opportunities, that they should examine with assiduous care their teaching methods and aims, should play an increasing part in the solution of educational problems and should influence more effectively the educational policies of the State.

Believing as I do that scientists should concern themselves with education and express themselves freely upon its problems, I have been impelled to take this occasion to practice, as fully as the occasion and the state of my ignorance permit, what I have preached. None can be more conscious than I of the need for substituting conclusions rigidly drawn after painstaking observation and experiment for opinions such as I have expressed. However, opinions, recognized as such, have a real place in the advancement of knowledge. If they provoke vigorous controversy, all the better so long as it is good tempered and on a basis of mutual respect, and provided it leads to further investigation and to decisions based upon knowledge rather than upon feelings and prejudice. It is with confidence that these propositions will receive such support as they merit and such opposition as they deserve that I lay them before the scientists and educators included in the Virginia Academy of Science and the Virginia Social Science Association and those interested in their concerns.

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GENERAL SCIENCE TEACHING IN VIRGINIA TODAY

THIS article considers the following topics: 1 The Place of General Science in the Modern School Curriculum, 2 Survey (partial) of General Science Courses given in Virginia in 1927-8, 3 The Training of General Science Teachers in the State Teachers Colleges of Virginia, 4 Survey of Textbooks, 5 Lack of Equipment, 6 Modern Methods of Teaching, 7 Worth-while Literature.

The above-mentioned topics constitute the high spots in a course on General Science given in the Summer School of the State Teachers College, Harrisonburg, Virginia, 1928.

1. *The Place of General Science in the Modern High School Curriculum*

General Science is fast winning for itself not only a permanent place in the high school curriculum but also a large place, if we may judge from the fact that the enrolment in this course in the United States is approximately equal to that of all other high school sciences combined.[1] There are several reasons why General Science has won this place for itself: The first and most important reason is that modern General Science courses actually meet the needs of the pupils in the first year high school. This

The following members of a Summer School (1928) class in the Organization of General Science co-operated in the preparation of this article: Sarah Hartman, Evelyn Kendrick, Maidie B. Hill, Christine Bolton, Alma Kline, Comena Mattox, Mollie Clark, and Viola Ward.

1. Frank—*How to Teach General Science*, p. 12.